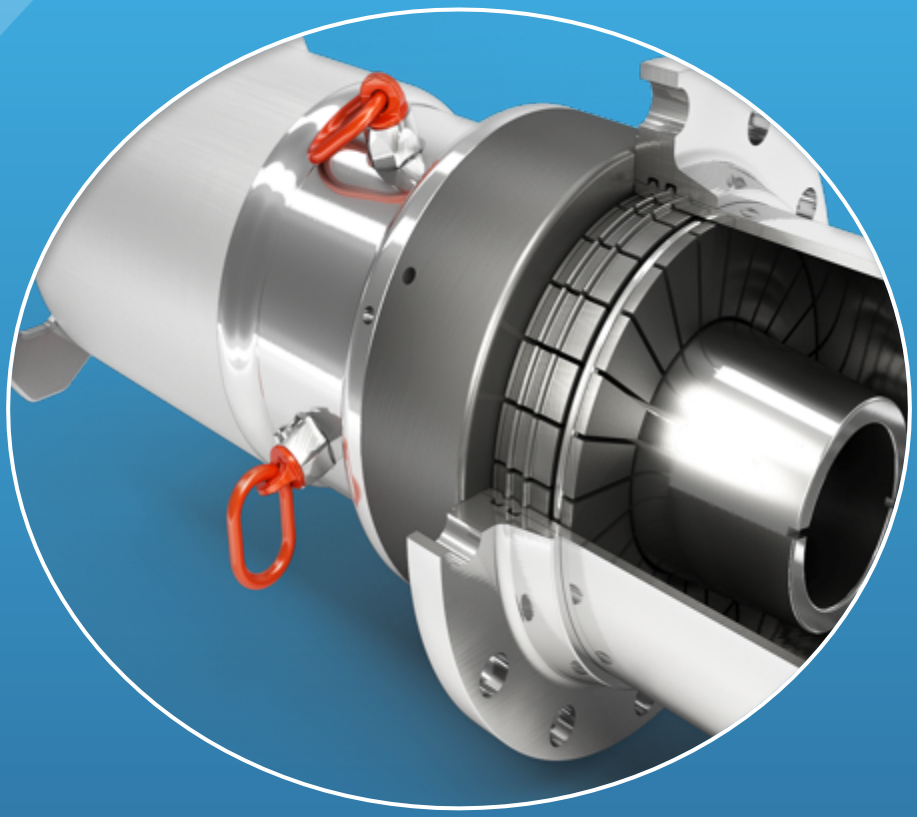
quickflange®



Technical Pack

This document summarises the technical elements of the Quickflange product and detailed descriptions of testing and accreditation of the product range. Supporting technical reports and further details are also available upon request

Rev – Jan16

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Introduction

Quickflange ("QF") is a product of Norwegian origin and has been developed with involvement of Oil and Gas industry organisations such Statoil, DNV and ABS. They have made significant inputs to the design of test programmes and the test criteria set, to prove the product's performance and integrity capabilities. Many customers have also dictated specific test programmes to ensure usability on a range of applications.

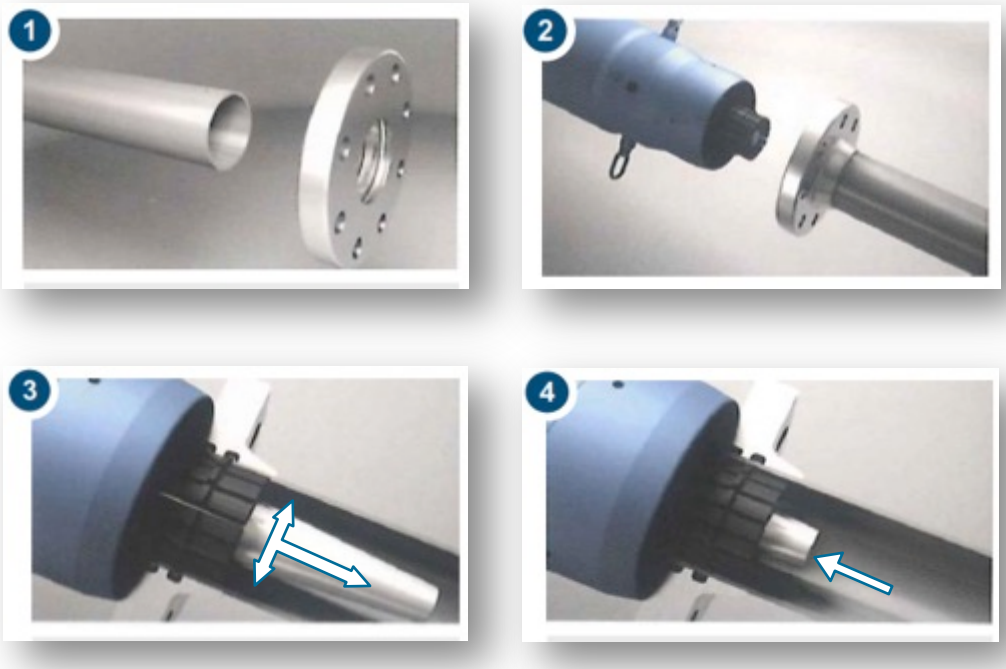
Quickflange is intended, and accredited as, a direct replacement for a welded flange, allowing the user to avoid welding / hotwork and complete installations in a fraction of the time taken to weld – without any reduction in performance. Since its introduction in 2003 Quickflange has seen its usage grow to over 5,000 applications with increased usage to bigger sizes, rating and criticality including materials from Carbon steel, Cunifer, Stainless steel, Monel, 6MO etc.

The technology also offers unrivalled flexibility in terms of cost, as all installation tooling is reusable and provided on a rental basis with scope for interchange ability, and long term hire packages.

Product Operation

How it Works

The standard "off the shelf" QF range is a modified standard weld neck flange, with a patented internal groove(s) pattern machined into it. The QF flange is slid over the pipe end and activated with a cold-forging tool. There is no spark or heat generated in the activation process, which takes up to 15 minutes to complete for the largest sizes (14") and far less for small sizes. The flange design is very simple (as seen below) with a pure metal-to-metal seal, and no moving parts, balls, springs, slips, seals or gaskets. The cold-forging tool forces the pipe wall into the grooves and this simultaneously affects the seal and grip on the pipe. The connector has an end stop to ensure correct installation position.



Product Range

Quickflange Connectors
The connector range is split into two categories – **Standard** "off the shelf" and Custom forged / Specials. The standard range typically covers the following:

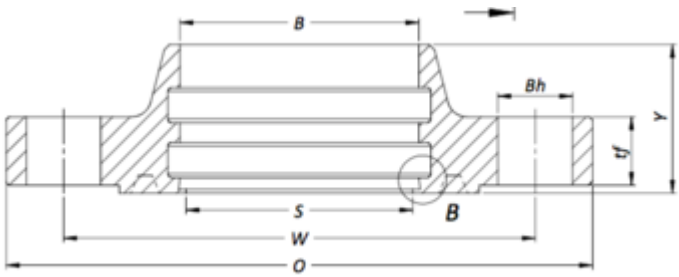
- Sizes up to 14"
- Pipe/flange materials – carbon steels, stainless steels (316, 22Cr, 25Cr, 6MO), CuNi, Monel, etc.
- Pressure ratings 150, 300lb in most schedules with certain ratings up to 900lb also available

Most of these connectors are held in stock and can normally be dispatched within 24 hours if needed.

The **Special** range are connectors which incorporate ALL the core elements of the standard range but are usually manufactured from a non standard flange, this can be for various reasons, such as –

- Higher pressures (up to 600bar) need more material than available on a standard ASME flange
- High Criticality service, such as Hydrocarbon use
- Subsea use
- Very thin wall (high OD/WT ratios)
- Customer specific qualification that need additional features, e.g. fire testing, additional load regimes etc.

This range will retain all the benefits of the standard range, and will go through the same design process / procedures. They also tend to have additional testing verification to suit individual applications.



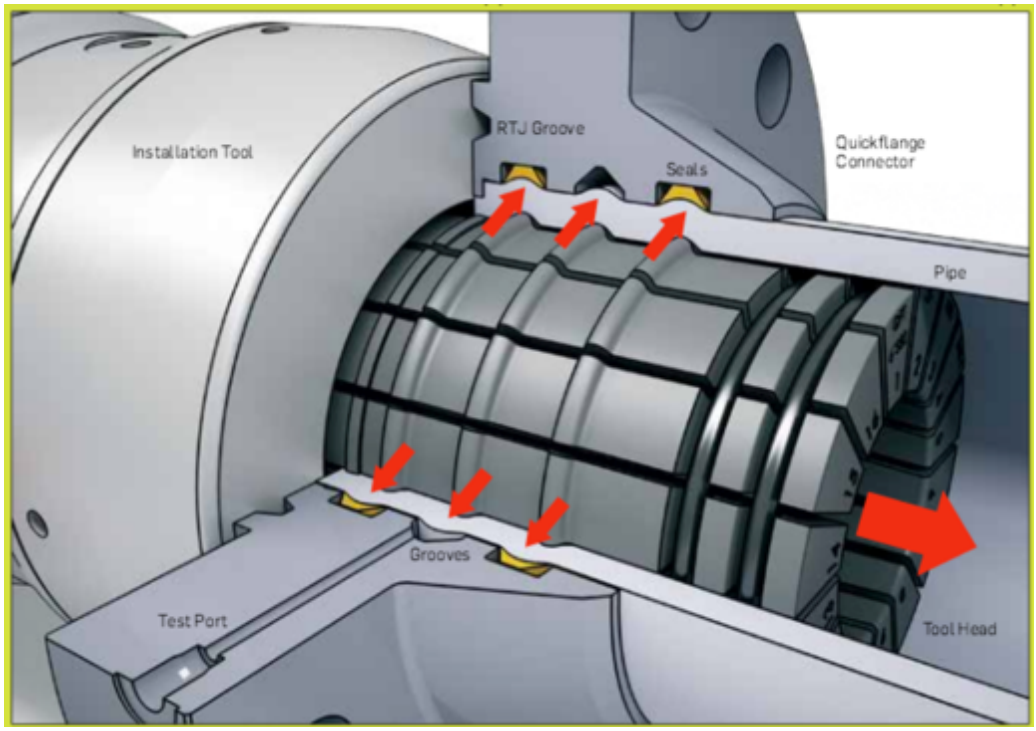
Installation Tooling Range & Typical QF Cross Section

Subsea Range

This range has been developed and introduced for the following reasons:

- Market demand - use all benefits from Topside to Subsea, namely simple operation, compact size, robust construction etc.
- Helps to drive Topside product range to higher pressures / critical service often associated with Subsea pipelines.
- Natural extension for product range to wider applications
- Product has potential to supply wider applications when compared to other mechanical connectors.

There are subtle differences needed to operate subsea, which include the inclusion of a test port (to verify sealing after activation), marine coating and environment end seals (in place of Belzona). The range is regarded as part of the specials range and applications are designed on a case by case basis.



Variations / Flexibility

Quickflanges are not limited to ASME flange terminations, the groove system has been adopted in many terminations types inc DIN flanges, hubs, sleeves, other preparatory terminations such as Taperlok etc.

Pipe Preparation

Quickflange connectors do not need any special pre-preparation for installation, they are designed to be installed on pipes which can be prepared under straightforward site situations and methods (Square cut and pipe coating removal).

Typically a standard QF connector can be installed on the following pipe prepared as follows:

Pipe End Cut

- As standard QF can accommodate ±0.5° end cut, typically cuts made by mechanical saws or diamond wire are suitable.
- All burrs produced by the cutting methods need to be removed prior to connector stab on.

Surface Preparation

- Pipe OD and ID to be free of loose debris such as scale, coatings, paint etc.
- Pipe OD to be free of coatings in both sealing and gripping areas.
- As a visual guide pipes need to stripped back of any coating to expose bare metal to a surface which resembles a rolled or mill finish. A finish similar to that produced by hand grinding or light sand blasting is sufficient.
- Typical surface finishes which are suitable, these have surface measurements ranging from R_a 1,5-6,0µm and R_{max} 10-55µm. See picture below.

Other

- Longitudinal Weld Seams – the reinforcement part of the weld (i.e. the protruding part of the weld) needs to be removed – blended back to pipe OD.
- Assuming pipe OD is within specified limits, pipes misaligned within the connector bore will not affect installation and performance.
- Any circumferential welds should be a minimum of 20mm away from the end of the QF connector.

Typical Pipe for Installation

Extreme Pipe Conditions

The Quickflange system has proved to be very robust, the pictures below show pipes where the conditions are far from recommended but were nevertheless successfully activated and tested.

Integrity

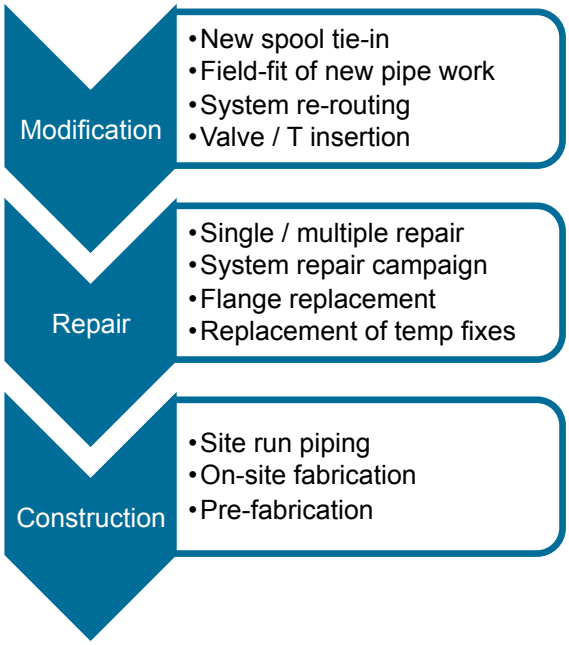
Job Verification Document

All applications have specific procedures, covered on Job Verification Document (JVD), these include all the relevant activation and test pressures. Each JVD can also be tied back to specific connectors ensuring full traceability for all connectors / applications / projects.

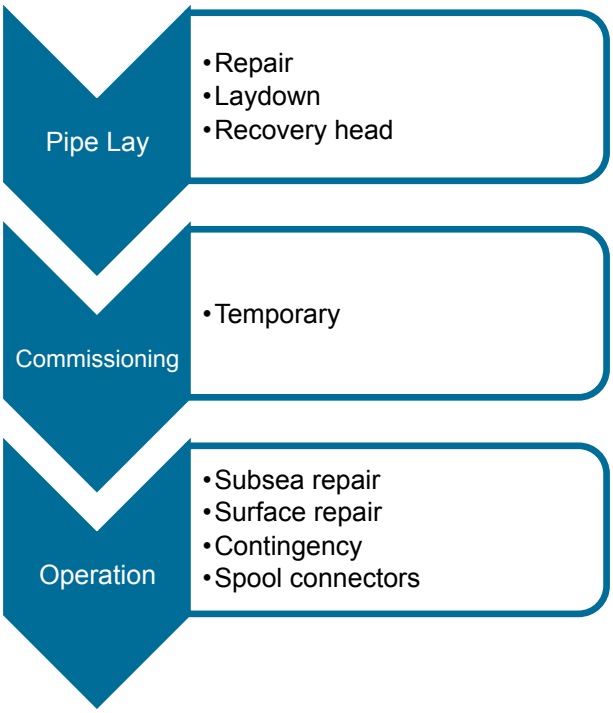
Applications

The following summarises typical applications and usage for the Quickflange product range.

Topside



Subsea

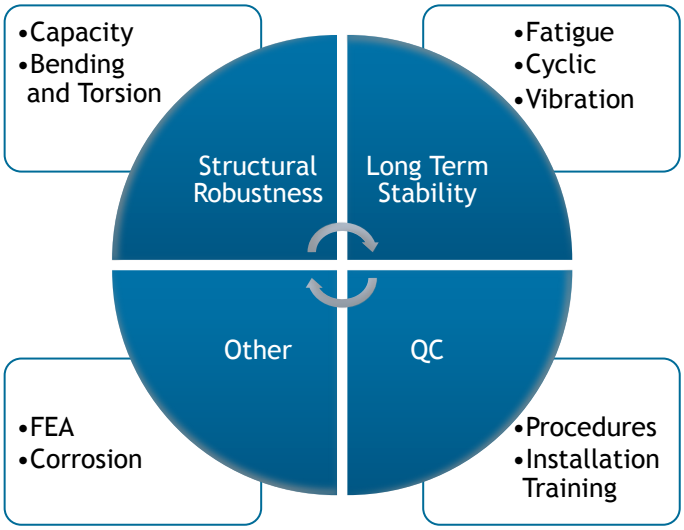


Qualification & Testing

Quickflange is extensively qualified and holds multiple accreditations with industry recognised bodies such as DNV and ABS. No connector design is released for sale and use without the application of tried and trusted design practice adopted from a vast qualification programmes completed throughout the products' history.

Quickflange has a continually growing product range and application usage meaning that it has an open programme of development to ensure that product integrity, understanding and knowledge is in line with it's widening application portfolio. This is also an expectation of customers, especially as the product range continues to be used on critical service both in pipeline media and installation challenges such a non ideal or standard pipe (corroded, damaged etc).

In essence Quickflange qualification is established to the following considerations and where required to industry recognised standards and codes:



Qualification Basis and Codes

Industry codes are followed to ensure Quickflanges are supplied to the latest standards, where required they are also designed to customer specific needs. Main codes applied during approvals qualification are:

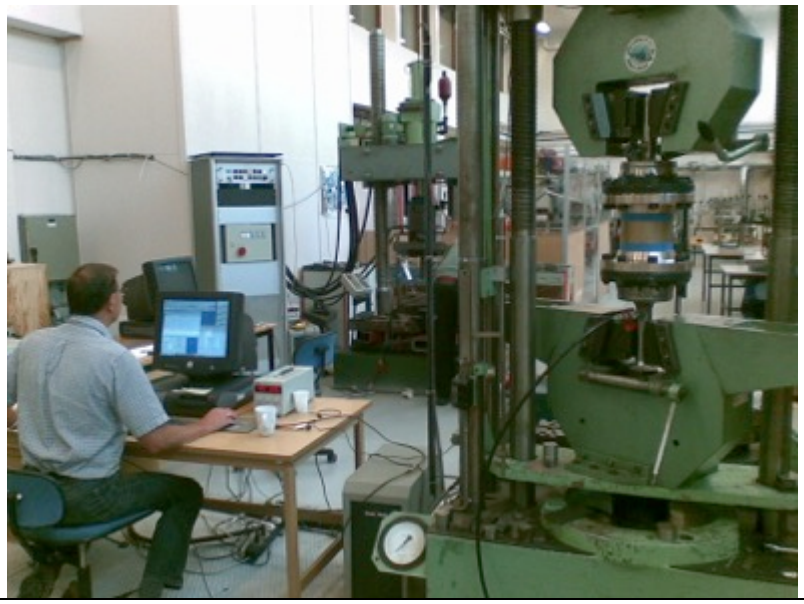
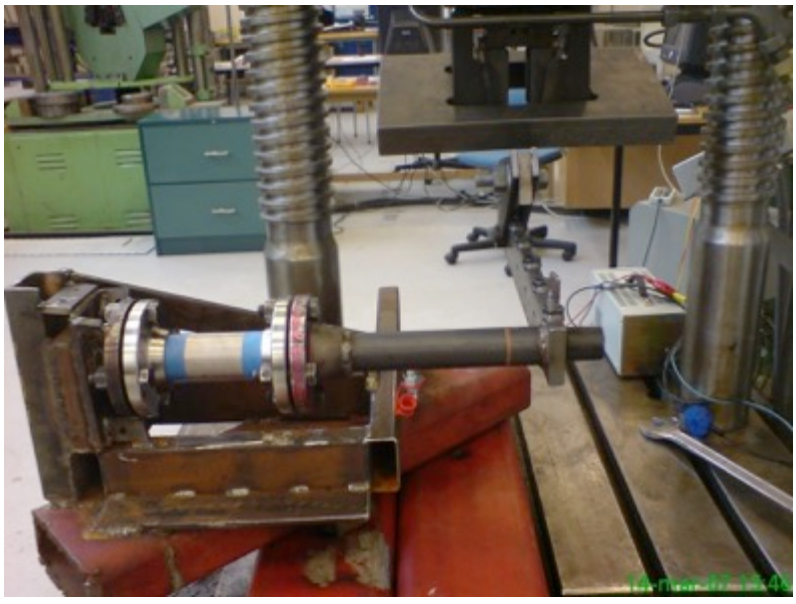
DNV GL Type Approval	DNV Rules for Classification of ships DNV Standards for Certification 2.9 No. 5-792.20 DNV Offshore Standards ASME B31.3
ABS	ABS Steel Vessel Rules 2011 ASME B31.3
Statoil	ASME B31.3 Pressure piping ASME B16.5

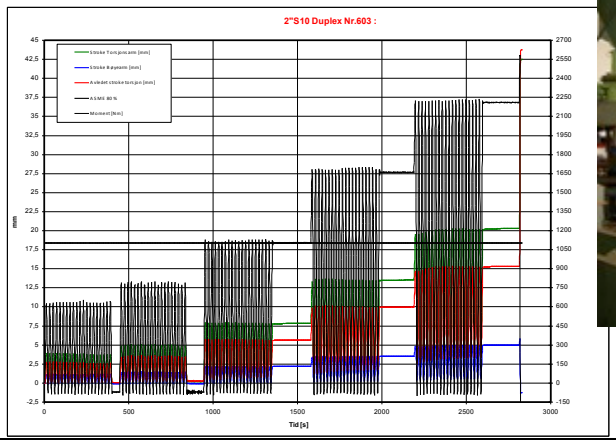
Core Qualification

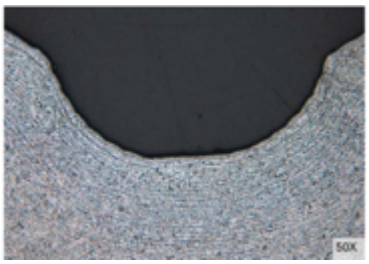
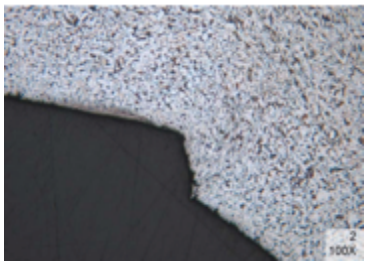
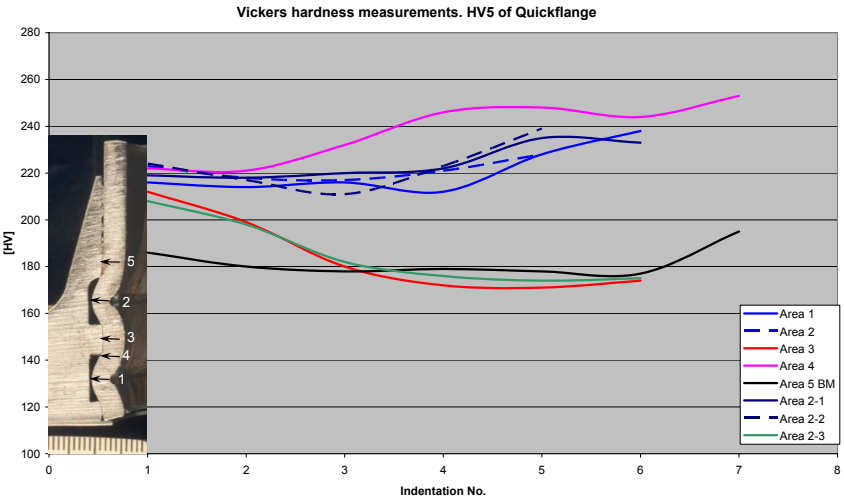
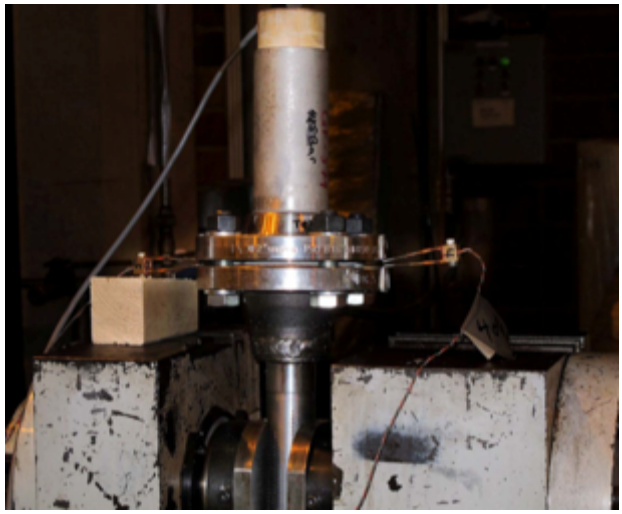
Quickflange has been qualified with third parties such DNV, ABS and Sintef, this section summarises the key core qualification. As the product range grows into bigger sizes and critical use more specific qualification has also been completed, this is described in the next section.

The main task of the core qualification was to demonstrate that the QF flange would maintain its structural integrity without leakage within a range of loads and test regimes. Working closely, with Statoil (who helped to define operational conditions), DNV were used to complete comprehensive qualification. Various materials and sizes were tested to ensure robustness across typical Quickflange applications.

The following tests and analysis were specified and carried out by DNV in order to qualify the Quickflange – **All testing / examinations were successfully completed**.

Test and Reasoning	Typical Set Up
Axial Tests High axial loads in process piping systems are relevant because of thermal longitudinal expansion of the pipes. This is governed mainly by the change in temperature from the initial condition. Axial Load Tests – Quickflange is loaded into a universal test machine and axial loads are applied, all results showed overcapacity of the Quickflange connection.	
Bending and Torsion Part of capacity testing, where in piping systems that operate under the conditions defined by Statoil the most probable loads that would cause high bending moment and torsion moment would be by the (unsupported) weight of part of the piping system and/or by misalignment caused by installation, maintenance or during service. The Quickflange is loaded in a specially designed rig to apply bending and torsional loads.	

Test and Reasoning	Typical Set Up
Fatigue / Cyclic Testing Cyclic regimes applied to relevant parts of the testing listed above to test for longevity / robustness. Results included 7000+ cycles at 125% of maximum allowable pipe load.	 
Vibration Testing Forced vibrations cannot be ruled out for piping systems, and the capacity of the QF connection to withstand forced vibration was a relevant part of the qualification programme. No leakage, relative movement or other signs of malfunction or failure of the QF flanges was observed during or after the tests. 10m cycles were observed on some set ups.	
Corrosion Testing The objective of the test to see if the integrity of the QF is impacted by heavy corrosion both from outside and inside environments. Aim was also to compare the corrosion performance of QF and regular welded flanges. The testing concluded that heavy corrosion from sea water exposure inside a pipe with QF or a severe outside environment had no impact on the integrity of the QF.	

Test and Reasoning	Typical Set Up
Metallographic examination To verify that the pipe expansion into the flange is not causing any detrimental damage to the pipe, non-destructive and metallographic examination were performed. The examination took a section of activated pipe for hardness and crack examination. The examination did not reveal any cracking at the contact areas between the expansion tool and the pipe or at the contact areas between the flange and the pipe. Areas of pipe deformation showed an increase in hardness but not to an extent of any concern.	 Inner side of tube at expansion tool imprint  Corner contact area between pipe and flange 
Belzona Testing These tests were done to ensure integrity of Belzona was not compromised during activation and flange make up. Belzona is used to protect against crevice corrosion. Connections were made up in the usual manner and subsequently examined. Various connections were examined including those specimens that went through mechanical testing outlined above. Inspection by stereo microscopy of the Belzona fillets did not reveal any cracks or indications of crack initiation.	

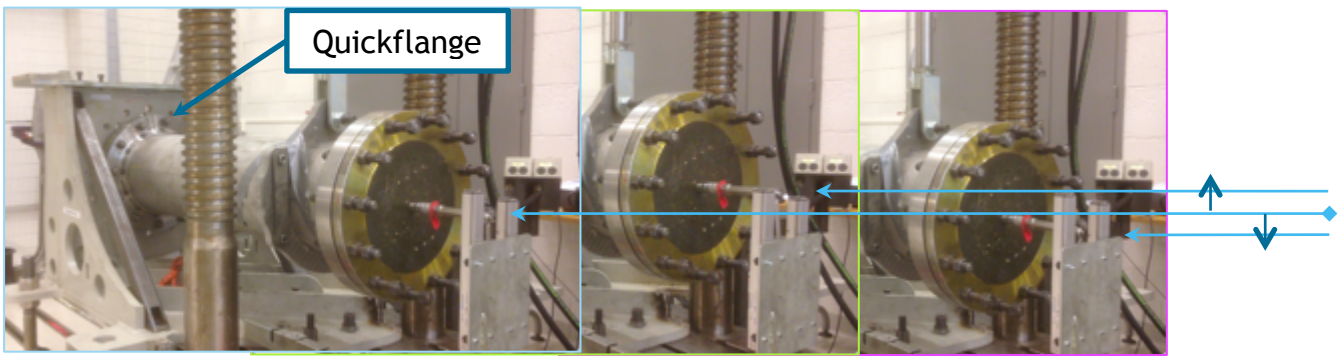
Test and Reasoning	Typical Set Up
Sour Testing The resistance to H_2S stress cracking (SSC) for the extruded cold deformed part of a pipe inside a single groove was investigated by SINTEF. None of the specimens failed during the test and no signs of cracking were revealed after the test. The test material has passed the test for all 3 H_2S-levels, i.e. both sweet, transition and sour service.	 
Fire Tests Specific tests for customers done in accordance with API 6FA. Pressurised assemblies fire tested to 700°C. All connectors subsequently and successfully retested at ambient temperature also. Sizes include 2in and 8in in Carbon Steel and 8in Cunifer. No leakage observed during testing.	

Extended / Recent Qualification

As part of growing the product range Quickflange has embarked on pushing its technology into Critical service (e.g. Hydrocarbon use), Higher pressures, bigger sizes and thin wall / high OD/WT applications, this has been for both Topside and Subsea applications. This expansion has not only been an internal desire but customers have also wanted the product to grow into new areas to take advantage of the benefits the technology holds over competitors and welding.

Examples of recent work are detailed in this section.

Qualification	Details
Thin Wall – "Exotic Materials"	This work was completed for BP Angola (FPSO). BP wanted to ensure robustness in terms of Fatigue. The challenge was a combination of thin wall (sch 10 or 4.5mm, and a OD/WT >70) on Super Duplex. The testing was completed in accordance with ASME 3.1J, essentially to compare and prove that the Quickflange connection would be at least equivalent to a weld. Stress Intensity Factors (SIF) of 1.13 was achieved meaning that the Quickflange joint could easily compare to a welded assembly. The programme involved challenging bending tests, the figure below shows a 12in connector being fatigue tested. The images show the assembly (flange bolted to bulkhead) at the two extreme positions around the centre point where it clearly shows the large extent of bending applied. No leakage was observed throughout these tests. The resulting solution meant that BP could complete connections without the need for specialist welding procedure / personnel, in minimal time around a strict shutdown schedule in a remote location where welding skills aren't easily available. The combination of materials and thin wall would have also proved difficult for other mechanical connector solutions. All work was completed with both BP and DNV witness. Multiple connectors have been installed successfully during 2014 / 15.



Qualification	Details
ABS Product Design Assessment (PDA)	Driven by applications on a FPSO project in Brazil, this work was towards proving specific robustness for Higher pressures and critical service using the clients approved third party (ABS) requirements. The test basis called for the flange/connection to be qualified to sustain a total of 10 million vibration cycles and 500 thousand pressure pulsation cycles without either leakages or damage. The vibration and the pressure pulsing being applied at the same period of time. The Quickflange connections showed no signs of leakage or damage during the entire testing period. The weakest point in the joint was actually the welded joint, no part of the Quickflange failed during this testing. The figures below show the test set up.

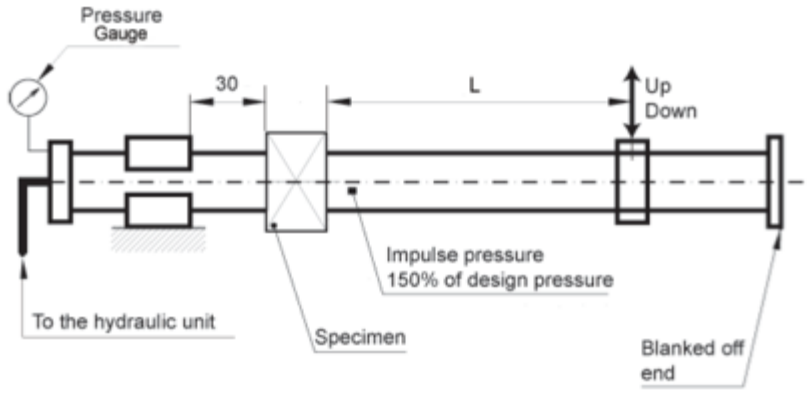


Figure 1: Test scheme from IACS standard

Qualification	Details
Proof / Burst Testing	Various load tests based around ASME BPVC Sec VIII Div1 UG-101. This is generally equivalent to 4 to 6 x operating pressure. Pressures achieved of over 600bar+

Images of burst test on Quickflange connectors, showing pipe rupture, note that in all cases the Quickflange remained totally intact.

Finite Element Analysis (FEA)

Quickflange recognised from early into its development that a parallel and continual approach of testing and theory development is essential to structured product development. Therefore alongside mechanical testing, analytical work such as FEA has / is being developed.

This work covers the following:

1) Deformation process
2) Applicable load scenarios for the Quickflange connection
3) Multiple Parameter studied:

    I. Material types
    II. Thin/thick wall
    III. High/low material yield

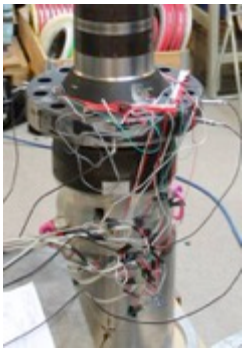
Fundamental work involves:

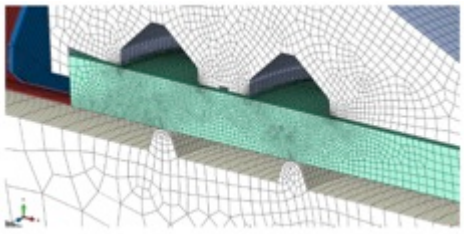
Optimising the analysis, both explicit vs implicit modeling.
Optimising meshing.
Calibrating the model both for the activation process and pipe pull out.

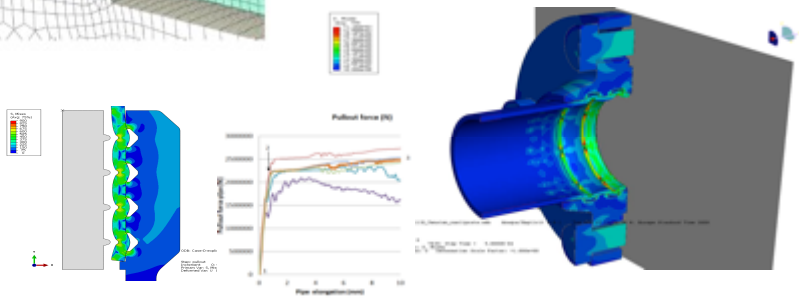
Specifically, the successful use of this method requires the ability to predict dimensional and stress/strain characteristics of the pipe and flange after the connection process in order to evaluate the connectivity to the adjacent flange as well as the leak tightness. In addition the ability to predict the process force during the connection process is needed in order to control the process and design the hydraulically actuated cold forming tool. It has been shown that it is possible to simulate this process using finite element (FE) methods and achieve a good correlation with experimental results. For this purpose a non-linear FE model of the flange, pipe and forming tool is developed and analysed using Abaqus.

Experimental work, including tensile material testing and Quickflange joining tests were carried out for material model calibration and Quickflange process model validation, respectively. The FE model results are in good correlation with experimental observations in terms of actuation force for the process, deformations and strains of pipe and flange during and after the process.

The developed FE model has been a useful tool for simulating the process within reasonable computational time as long as careful considerations are given to model complexity, material parameters, friction, and pipe geometry tolerances.







Technical Partners

University of Agdar

Quickflange's technical centre / department is located in southern Norway close to a technical university in Agdar. Quickflange has a longterm relationship (10 + years) with its mechanical engineering department and associated laboratories. This means that Quickflange are able to seek help with technical and practical testing facilities on a regular basis. The testing facilities are regularly used for any qualification purposes.

The Universities facilities include:

- Microscopy
- Hardness Testing
- Fatigue Bending Testing
- Fatigue Pull Testing
- Tensile Testing of steel and other materials
- Crevice corrosion testing
- Annealing / Heat Treatment
- Witness of pressure testing

Quickflange has a long term agreement to use the university facilities at short notice including out of hours working when needed. **The university is also being used as part of a PhD programme for developing the FEA modelling as specified in the previous section.**

Corrosion Studies

Corrosion performance has been extensively and independently assessed. These have been covered by third parties such as Sintef to ensure the latest and most knowledgeable evaluation is considered. In essence the main components of a Quickflange are forging equivalents of the pipe material and similar to standard flanges. Outer surfaces can also be marine coated if needed. Protection against crevice corrosion is achieved by application of Belzona (Topside) or an outer lip seal (Subsea)

The following Corrosion threats have been evaluated and all conclusions state that the protection and practices used in Quickflanges will not pose an issue for long term use both topside and subsea:

- Crevice Corrosion
- Materials Compatibility using guiding standards such as Norsok M-001
- Sour Service
- Hydrogen Embrittlement inc HISC

Track Record

Quickflange has gone from strength to strength and upto 2015 **over 5,000** connectors have been supplied from 3/4in to 14in. The charts below give some insight of specifics of its track record…….

Wall Thickness Supplied

2.5mm (CuNi)
3.5mm (CuNi)
3mm (CuNi)
4.5mm (CuNi)
5.5mm (CuNi)
7.0mm (CuNi)
SCH 10
SCH 10S
SCH 20
SCH 30
SCH 40
SCH 40S
SCH 60
SCH 80
SCH 80S
SCH 120
SCH 160

Materials

A182 F316
A350 LF2
A105
A182 F321
A182 F44 6Mo
A182 F51 Duplex
A182 F53 SUPER DUPLEX
A182 F55 Super Duplex
A694 F52
CuNI
F44 6MO
MONEL 400
SS - A182 304, 316 etc

Service

AAAF	Diesel	Instrument Air	Service Line
AC	Diesel Additive	Jet Water	Service Water
Aeration	Diesel Exhaust	Lubricating oil	Sprinkler
AFFF	Diesel Oil	MEG	Steam
Air	Drain	Methanol	Steam & Drain Oily Water
Air Plant	Drain - Open	Mud	Sump Pile Gas
Anti Foam	Drain flow	Mud / cement low pressure	Sweet gas
Atmospheric Vent	Drain including oil	Mud / Drill Cuttings	Test Chem.
Ballast water	Drain Invert mud	Mud Drain	Vent
Barite	Drain line	Mud Line	Vent line for Silicon Oil
Base Oil	Drain mud	Mud Return	Vent Produced Water
Biocide	Drain Open	N2	Vent
Biofuel	Drain Sewer/Sanitary	Nitrogen	Ventilation
Boiler Feed Water	Drain Water	OBM	VOC
Brine / BR	Drains	Ocean Water	Waste Water
Bulk Air	Drill Cuttings	Oil	Water
Bulk Cement / Open Drain	Drill Water	Oil Based Mud	Water - Potable
Cement	Drinking Water	Oil Drain	Water desalinated fresh
Chemical X,	Fire water system	Oil Fuel (Diesel)	Water Dump Line
Chemical, dosing / Drill Water	Fire system Foam	Oil Hydraulic	Water fresh / glycol - cooling
Chemicals	Fluid completion	Oil low toxic	Water Injection
Closed Drain	FRAC	Oil Seal	Wax
ColB-Ni	Fresh Water	Oil vent	Vent Air
Completion	Fuel Gas	Oil, Trial, test tank	
Condensate	Gas inert (N2)	Oily Drain	
Cooling Medium	Gas relief header	Oily Water	
Corrosion INM.	Gas Vent	Oxygen Scan.	
Crude Oil	Glycol	Plant Air	
Deluge	Glycol / Water	Produced Water	
Deluge / Fire Water	Glycol / water Chem	Jet helifuel	
Deluge potable water	Hax tank	Reclaimed Oil / Oily Water	
Demulsifier	Hazardous Drain	Salt Water	
Desalted Water	HEAT	Sanitary	
	Heat Medium	Scale FNM.	
	Heating Media	Seawater	
	Hot Oil		
	Hot Water		
	Hydraulic Oil		
	Inert Gas		

Features and Benefits Summary

Quick & Simple Installation

NO Hot Work

Safe and Easy

Permanent

As a Welded Connection

Flexibility

Multiple Flange / Termination Options
Multi use – Multi-Coverage Tooling

Fully Accredited

DNV

FPAL empowered by Achilles Registered

Registration no.: 10051880

DESIGN ABS ASSESSED

IQNet CERTIFIED MANAGEMENT SYSTEM

NORWEGIAN ACCREDITATION

NS-EN ISO 9001:2008

Quickflange Norway AS

Lagerveien 12A, 4033 Stavanger, Norway Phone: + 47 41 48 70 00
mail.no@quickflange.com

Quickflange Technology AS

Hovedgata 10, 4900 Tvedestrand, Norway Phone: +47 41 48 70 00
mail.no@quickflange.com

Quickflange UK Limited

Wellheads Industrial Centre Unit E27 Wellheads Crescent Dyce, Aberdeen. AB21 7GA, UK Phone: +44 (0) 1224 722265
mail.uk@quickflange.com